UNCLASSIFIED

AD NUMBER

AD-343 291

CLASSIFICATION CHANGES

TO   **UNCLASSIFIED**

FROM   **CONFIDENTIAL**

AUTHORITY

OCA; May 1, 1975

19990618013

THIS PAGE IS UNCLASSIFIED

UNCLASSIFIED

AD NUMBER

AD-343 291

NEW LIMITATION CHANGE

TO

DISTRIBUTION STATEMENT: A

Approved for public release; Distribution is unlimited.

LIMITATION CODE: 1

FROM

No Prior DoD Distr Scty Cntrl St'mt Assgn'd

AUTHORITY

USNOL via Ltr; Aug 29, 1974

THIS PAGE IS UNCLASSIFIED

CONFIDENTIAL

NOLTR 63-81

THE EXPLOSIVE PROPERTIES OF THE
AMINO-SUBSTITUTED, SYMMETRICAL
TRINITROBENZENES (U)

MAY 1963

DDC

OCT 14 1963

TISIA A

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 63-81

CONFIDENTIAL

GENERAL DECLASSIFICATI

SCHEDULE

IN ACCORDANCE WITH

DOD 5200.1-R & EXECUTIVE ORDER 11652

THIS DOCUMENT IS

CLASSIFIED BY_____.

Subject to General Declassification Schedule of

Executive Order 11652-Automatically Downgraded at

2 Years Intervals- DECLASSIFIED ON DECEMBER 31,_19

BY

Defense Documentation Center

Defense Supply Agency

Cameron Station

Alexandria, Virginia 22314

AL
NOLTR 63-81

THE EXPLOSIVE PROPERTIES OF THE AMINO-SUBSTITUTED,
SYMMETRICAL TRINITROBENZENES (U)

By N. L. Coleburn, B. E. Drimmer

ABSTRACT: The shock sensitivity and failure diameters of four
explosive compounds of the trinitrobenzene series: 1, 3, 5-
trinitrobenzene (TNB), 1-amino 2,4,6-trinitrobenzene (TNA),
1,3-diamino 2,4,6-trinitrobenzene (DATB) and 1,3,5-triamino
2,4,6-trinitrobenzene (TATB) are functions of the number of
amino groups, heats of formation and oxygen balance. The most
sensitive, TNB, has the lowest heat of formation and oxygen
balance. Detonation failure occurs at diameters of $\leq$ 0.3 cm TNB,
0.3 cm TNA, 0.53 cm DATB and 1.3 cm TATB. The detonation velocity-
charge density relation, $D_{(m/sec)} = 2480 + 2852 \, \rho_{(g/cm^3)}$, and the
measured detonation energies of 815 ± 15 cal/g are the same for
each series member. The measured detonation pressures are 259.4
kb and 174.6 kb for TATB at densities of 1.80 g/cm^3 and 1.50 g/cm^3,
251.0 kb for DATB at 1.80 g/cm^3, and 219.2 kb for TNB at 1.64g/cm^3.
Rapidly applied shocks, with peak pressures as high as 100
kilobars in the NOL wedge test, fail to detonate 12.7 mm thick
TATB samples. On the other hand, under such shock conditions,
the other three compounds are at least as sensitive as Composi-
tion B. Each, however, is less sensitive than pressed TNT to
slowly applied pressure pulses such as might develop in an
impact accident.

EXPLOSION DYNAMICS DIVISION
EXPLOSIONS RESEARCH DEPARTMENT
U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

L
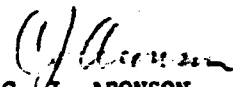
NOLTR 63-81   May 1963

THE EXPLOSIVE PROPERTIES OF THE AMINO-SUBSTITUTED, SYMMETRICAL
TRINITROBENZENES (U)

The purpose of this work was to study the effect of systematic
changes in molecular structure on the shock sensitivity and
detonation properties of a chemically-related series of
explosives. The results of this approach should be of value to
the synthetic organic chemist and the research worker concerned
with sensitivity of explosives and propellants. The work was
done under WepTask No. RUME 4E 000/212-1/F008-10-004, Study of
Explosive Properties.

                                R. E. ODENING
                                Captain, USN
                                Commander

                                C. G. ARONSON
                                By direction

                                ii

CONTENTS

ILLUSTRATIONS

TABLES

CONTENTS

TABLES

1. INTRODUCTION

1.1 **Previous Studies.** Several studies have been reported correlating the chemical structures of explosive organic compounds with their thermal stabilities (1,2)*, impact sensitivities (3,4,5), and other explosive properties. Perhaps most pertinent to the results reported in the present paper is Robertson's work (2) in 1921, wherein thermal stability, detonability, and shock sensitivity were related to the heats of formation of several organic explosive compounds whose compositions were varied by substitution of various alkyl groups. Forty years later Blinov (5) reported the sensitivity of various dinitro-compounds of benzene to impact, friction, heat, and flame. In each of these studies, the duration of the explosion initiating stimulus was generally of the order of milliseconds. Under such long duration stimuli, many workers (e.g. 6,7,8) consider the explosive response (such as a "go" in the impact hammer machine) a phenomenon intermediate between a thermal decomposition and a detonation. On the other hand, initiation to detonation may occur in times of the order of a microsecond or less, when the stimulus is applied by means of a shock wave transmitted through air (9), water (10,11), or solids (12,13,14). Comparison of the response of members of a chemically related series of compounds to such more rapidly applied stimuli had not yet been made. This paper will discuss such a set of data.

1.2 **The Amino-Substituted Trinitrobenzenes.** A group of four chemically related explosive compounds can be considered to have been formed by the substitution, one at a time, of an amino (NH_2) group for a hydrogen, in symmetrical trinitrobenzene.

1,3,5-trinitrobenzene ------------------------------ TNB
1-amino-2,4,6-trinitrobenzene --------------------- TNA**
1,3-diamino-2,4,6-trinitrobenzene ---------------- DATB
1,3,5-triamino-2,4,6-trinitrobenzene ----------- TATB

(The initials on the right are those commonly used to identify the particular compounds.) These compounds are well known from the chemical literature (15, 16, 17). For ready reference, their various physical, chemical and explosive properties have been assembled and tabulated in Table 1 (together with the

---

* References will be found on page 23.
**Another name for this compound is "2,4,6-trinitroaniline," from which "TNA" is derived. Even more commonly, this compound is known as picramide.

TABLE 1

Physical, Chemical, and Explosive Properties

Property	TNB	TNA	DATB	TATB	TNT
Structural Formula	(ring: NO_2, CO_2, O_2N)	(ring: NO_2, NH_2, O_2N)	(ring: NO_2, NH_2 NO_2, NH_2, O_2N)	(ring: NO_2, NH_2 NO_2, H_2N, O_2N, NH_2)	(ring: NO_2, CH_3 NO_2, O_2N)
Molecular Weight	213	228	243	258	227
Crystal Density (g/cm^3)	1.688	1.762	1.837	1.938	1.651
Melting Point (°C)	121	188	286	450d	81
Heat of Formation (kcal/mole)	-11.40 (18)	-20.07 (19)	-29.23 (20)	-36.85 (20)	-17.81
Activation Energy (kcal/mole)	--	--	65.8 (21)	--	37.0 (21)
Specific Heat (cal/g/°C)	--	--	0.261 (21)	--	0.264 (21)
Thermal Conductivity (10^{-4} cal/sec/cm-°C)	--	--	6.19 (21)	--	4.61 (21)
Vacuum Stability					
100°C (cm^3/g/48 hrs)	0.0	0.0	0.1	0.1	<0.1
260°C (cm^3/g/hr; 2 hr exposure)	<0.10	--	3-4	0.8	--
280°C (cm^3/g/hr; 2 hr exposure)	--	--	52.5 (22)	4.5 (22)	--
Experimental Density (g/cm^3)	1.64	1.74	1.800	1.802	1.619
Detonation Velocity (m/sec)					
(at exper. density)	7269	7440	7600	7658	6700
dD/dρ (m/sec)/(g/cm^3)	2852	2852	2852	2852	3225 (23)
Failure Diameter (cm)	≤0.3	0.3	0.53	1.3	0.25
Detonation Pressure (kb)	219.2	241*	251	259	187
Detonation Energy (cal/g)	811	827	800	829	692
50% Impact-Hammer Height (cm)	100	177	>320	>320	200
Plate Push Value (ft/sec)					
At 93% crystal density	2946	2347**	3028	3124	2830
At 98% crystal density	--	--	3130	3229	2930

d - decomposes
* - Calculated from $P = \rho D^2/4$
** - TNA/Zytel 95/5 (Plastic-bonded explosive)

properties of TNT for comparison), and therefore only a brief
description of each is given here.

Trinitrobenzene is a yellow solid of crystal density,
1.688 g/cm^3. Perhaps because of its resonating molecular
structure, which permits intramolecular bonding, TNB is one of
the most heat stable explosives known. When heated, TNB gives
off only a trace of gas at 180°C, nearly 60°C above its melting
point, evolves less than 0.1 cm^3/g/hr at 260°C(2) and does not
explode until 520°C (1). TNB can be made from trinitrotoluene
(TNT) by oxidation and decarboxylization of the resulting
trinitrobenzoic acid. Kast (24) measured the detonation
velocity as a function of charge density for trinitrobenzene
using the Dautriche method. Koehler and Desvergnes (25) also
used this method to measure a velocity of 7441 m/sec for cast TNB,
some 2 percent above our value (below).

TNA, picramide, is a yellow, needle-like solid melting at
188°C. Its crystal density is 1.762 g/cm^3. It can be prepared
by nitrating aniline in glacial acetic acid. Brisance (3) is
the only explosive property reported to date for picramide.

The NOL synthesis (26) and related studies (27, 28) of DATB
and TATB have renewed interest in these heat resistant
explosives. DATB has a crystal density of 1.837 g/cm^3 (23°C),
melts at 286°C, and although less stable than TNB, decomposes
at a negligible rate at 204°C (24), TATB, the most dense member
of the series (crystal density, 1.938 g/cm^3), has the highest
melting point, 450°C, and is the least sensitive to mechanical
shocks.

2. DETONATION VELOCITY MEASUREMENTS

2.1 Charge Preparation. For charges with densities from
1.6 to 1.9 g/cm^3, 5.0-cm diameter pellets were obtained by
standard pressing techniques and then machined to smaller
diameters as necessary for the specific individual tests. Charges
with densities from 1.2 to 1.5 g/cm^3 were obtained by press
loading (at pressures up to 8,000-10,000 psi) 15-gram increments
of the compound into 4.4 to 5.4-cm internal diameter, 0.15-cm
thick, copper or aluminum tubes*. Charges with densities below
1.2 g/cm^3 were prepared by hand-packing the material into pyrex
glass tubing. The detonation wave from charges confined in the
metal tubes was observed through a series of small, evenly spaced
holes drilled through the metal casing. The initiating explosive
train consisted of a U.S. Engineer's Special Electric Detonator,
a 5.1-cm diameter plane-wave generator (Baratol-Composition B),
and a 5.1-cm diameter, 5.1-cm long tetryl pellet.

---

* With the exception of 2 shots confined in Lucite (Table 4, nos.
3 and 4) in which the explosive was pelleted and slipped into the
confining Lucite tube.

2.2 Detonation Velocity—Charge Density Relationship. The measured detonation velocities of each series member are listed in Tables 2 to 5, and are plotted in Figure 1. The line drawn through the data represents the measurements previously reported (28) for DATB whose detonation velocity varies linearly with charge density according to

$$D = 2480 + 2852 \, \rho_o \quad (\pm 25 \text{ m/sec}) \tag{1}$$

Velocities of the other series members have an average deviation of 50 m/sec from this line. The agreement indicates the detonation velocity—charge density relationship is the same for all members of the series: detonation velocity is very insensitive to the number of amine groups.

2.3 Failure Diameter. The failure diameter was determined by detonating pyramidal charges consisting of three cylindrical pellets, 2.54, 1.22, and 0.64-cm diameter, stacked in order of decreasing diameter. On top of the 0.64-cm diameter pellet was placed a 1.25-cm long, truncated conical section, tapering from 0.64-cm diameter at its base to 0.32-cm at the top. The conical section was not used with trinitrobenzene because of machining difficulties. Detonation of the pyramidal charges of TATB, DATB and TNA gave normal velocities, with detonation failure occurring at charge diameters: 1.3 cm (TATB), 0.53 cm (DATB), and 0.3 cm (TNA). The failure diameter of trinitrobenzene was not ascertained by this method. However detonation propagated without measurable diminution of rate up to the end of 3.8-cm long, 0.6-cm diameter TNB pellets.

3. MEASUREMENTS OF THE CHAPMAN-JOUGUET PRESSURES

3.1 Experimental Method. The Chapman-Jouguet pressures were experimentally determined using the water tank, or aquarium technique (29). For convenience, this method is described briefly: the lower end of a cylindrical charge is immersed to a depth of 6 cm in distilled water. The upper end of the charge, protruding above the surface, is initiated to detonation by a plane-wave generator. As a result, the detonation wave strikes the water at normal incidence, and a shock wave is transmitted into the water. The shadowgraph of the shock wave in the water is recorded by a rotating-mirror smear camera using collimated light from an electrically exploded wire light source. Analysis of the record then yields the velocity of the shock in the water as a function of distance from the bottom of the charge. The velocity (U_{H_2O}) of this shock at the water-charge interface is then obtained by extrapolation. Having U_{H_2O} the equation of state of water (30) is employed to get the particle velocity (u_{H_2O}) and the peak pressure (P_{H_2O}) in the water at the water

TABLE 2

Detonation Velocity of Trinitrobenzene (TNB)

Charge No.	Diameter (cm)	Length (cm)	Confinement	Density (g/cm³)	Detonation Velocity (m/sec)
1*	0.64	2.54	None	1.670	7160
	0.64	1.27	"	1.670	7160
	1.27	1.30	"	1.657	7160
	1.27	1.35	"	1.657	7160
	2.54	2.39	"	1.662	7160
	2.54	2.56	"	1.662	7160
	2.54	2.54	"	1.662	7160
	2.54	2.39	"	1.647	7160
2	5.24	15.1	Copper	1.264	6090
3	5.24	15.1	"	1.234	6100
4	5.24	15.1	"	1.265	5905
5	4.62	13.7	Glass	1.644	7269

* Charge 1 was in the form of a pyramid, made of cylinders.

TABLE 3

Detonation Velocity of Picramide (TNA)

Charge No.	Diameter (cm)	Length (cm)	Confinement	Density (g/cm³)	Detonation Velocity (m/sec)
1*	Conical**	2.34	None	1.726	--
	0.64	1.34	"	1.726	7345
	1.27	1.34	"	1.746	7310
	1.27	2.76	"	1.750	7310
	2.54	2.76	"	1.737	7560
	2.54	2.74	"	1.746	7560
	2.54	2.74	"	1.744	7560
	2.54	2.77	"	1.728	7560
2	4.43	15.24	Copper	1.485	6800

* Charge 1 was in the form of a pyramid, consisting of one conical, and three cylindrical sections.
**Diameter uniformly decreased from 0.63 cm to 0.32 over 2.34-cm length.

TABLE 4

Detonation Velocity of DATB

Charge No.	Diameter (cm)	Length (cm)	Confinement	Density (g/cm^3)	Detonation Velocity (m/sec)
1*	Conical**	1.250	None	1.816	***
	0.64	2.540	"	1.816	7620
	1.27	2.644	"	1.815	7620
	2.54	7.861	"	1.809	7620
2	5.47	13.40	Glass	0.901	5050
3	5.47	15.31	Lucite****	1.427	6600
4	4.48	15.53	"	1.375	6470
5	4.44	15.26	Aluminum	1.381	6470
6	4.44	15.27	"	1.285	6130
7	4.44	15.27	"	1.205	5880
8	5.08	15.80	None	1.788	7570
9	5.08	20.47	"	1.793	7580

* Charge 1 was in the form of pyramid, made of cylinders, plus a conical apex.
** Diameter uniformly decreased from 0.64 to 0.32 cm over 1.25 cm length.
*** Failure diameter = 0.53 cm.
**** Wall thickness - 0.20 cm.

TABLE 5

Detonation Velocity of TATB

Charge No.	Diameter (cm)	Length (cm)	Confinement	Density (g/cm^3)	Detonation Velocity (m/sec)
1*	Conical	0.64	None	1.880	--
	0.64	1.27	"	1.881	--
(Boostered	1.27	1.32	"	1.874	7610
by 75/25	1.27	1.35	"	1.879	7610
Cyclotol)	1.27	1.35	"	1.880	7610
	1.27	1.32	"	1.878	7614
	2.54	2.57	"	1.882	7772
	2.54	2.57	"	1.875	7772
2**	Conical		None	1.864	7650
	1.27	2.54	"	1.863	7650
(Boostered	2.54	2.54	"	1.860	7745
by Tetryl)	2.54	2.54	"	1.864	7745
	5.08	5.08	"	1.862	7745
	5.08	5.08	"	1.864	7745
3	5.08	5.08	Glass	1.802	7658
4	4.45	15.24	Glass	1.508	6555

*   Tapered to 0.31 cm from 0.64 cm over 0.64 cm length.
    Detonation did not propagate into 0.64-cm diameter section.
** Tapered to 0.64-cm diameter from 1.27-cm diameter over
    1.9-cm length.
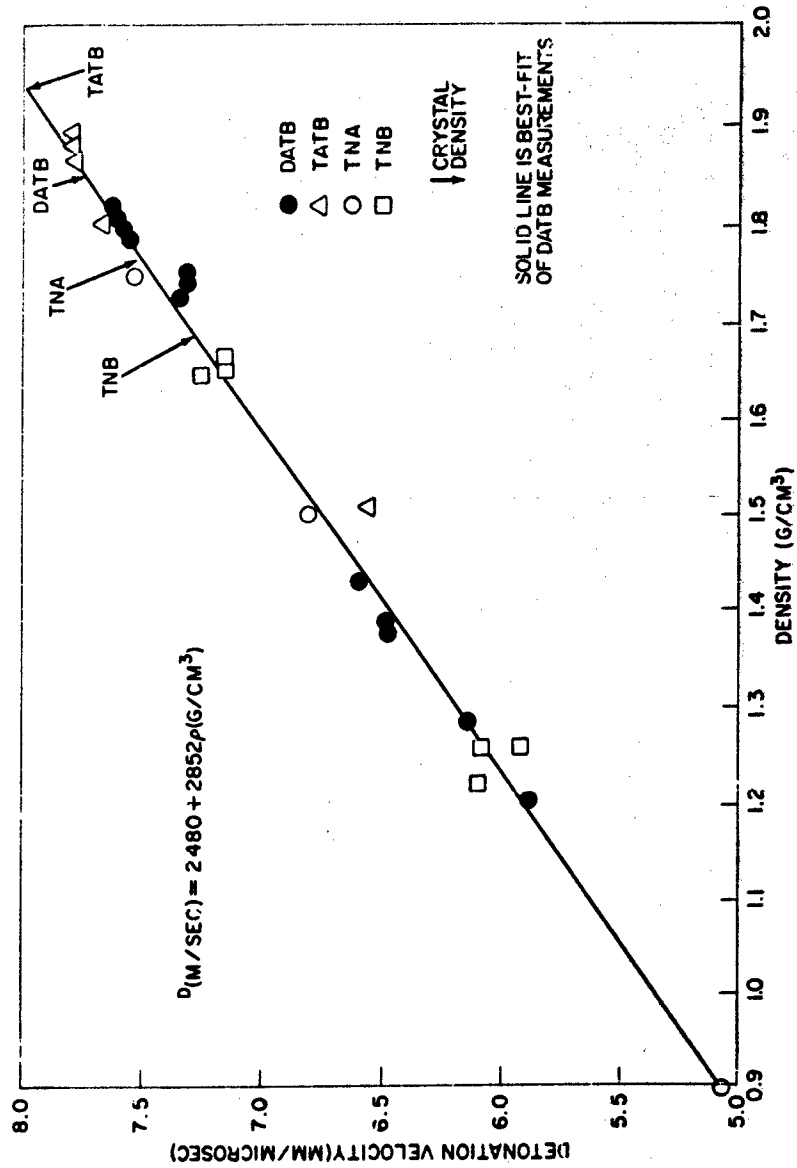
FIG. 1 DETONATION VELOCITY AS A FUNCTION OF CHARGE DENSITY.

$D_{(M/SEC)} = 2480 + 2852\rho_{(G/CM^3)}$

explosive interface. The Chapman-Jouguet pressure for the explosive is then obtained by iterating values of "k" (the isentropic exponent of the product gas expansion) between two relations that are derivable (28) from the Riemann postulate as applied to an isentropic expansion of the product gases until the same P_{CJ} is obtained from both equations:

$$P_{CJ} = \frac{\rho_o D^2}{k+1} ,$$ (2)

a.id

$$P_{CJ} = P_{H_2O} \left[1 - \frac{(k^2-1) U_{H_2O} - (k-1) D}{2kD} \right]^{-\frac{2k}{k-1}}$$ (3)

Here, as usual, D represents the detonation velocity of the explosive, and ρ_o is its density before detonation.

Using an equation derived by Jacobs (31) and Price (32) the experimentally determined values of D and k permit a calculation of the energy of detonation, Q,

$$Q = D^2/2 \ (k^2-1)$$ (4)

3.2 **Results.** Values of the detonation parameters obtained by this water shock method for (normal charge densities) DATB, TATB, and one plastic-bonded composition of DATB, are listed in Table 6 where they are compared with those of TNT. These measurements are considered to be correct to within 1% in shock velocity, leading to relative errors of approximately 3 percent in the Chapman-Jouguet pressure, 3 percent in k, and 6 percent in detonation energy.

4. DETONATION CALCULATIONS

4.1 **Heats of Reaction.** The heat of reaction, Q, can be estimated if one assumes that on detonation, the order of forming the product gases is $H_2O_{(g)}$, $CO_{(g)}$, $CO_{2(g)}$

TABLE 6

Chapman-Jouguet Pressure, Energy, and Isentropic Exponent From Water-Shock Measurements

Explosive	ρ(g/cm³)	D(m/sec)	U_{H_2O} (m/sec)	u_{H_2O} (m/sec)	P_{H_2O} (at HE-H_2O interface)(kb)	P_{CJ} (kb)	k	Q (cal/g)
TNB	1.64	7269	5835	2522	147.0	219.2	2.96	811
DATB	1.79	7585	5980	2624	156.9	251.0	3.10	800
DATB/Zytel (95/5)	1.71	7200	5839	2524	147.4	224.0	2.97	792
TATB	1.80	7658	6071	2685	163.0	259.4	3.07	829
TATB	1.50	6555	5519	2303	126.9	174.6	2.71	808
TNT	1.62	6790	5532	2312	127.6	187.2	2.99	692

$C_{(s)}$ (if there is insufficient oxygen to form CO_2) (33, 34, 35, 36). With this assumption, the reactions would be

$$\underline{\text{TNB:}} \quad C_6H_3N_3O_6 \;\text{----}\; 1.5\,H_2O_{(g)} + 4.5\,CO + 1.5\,N_2 + 1.5\,C_{(s)} \quad (5)$$

$$\underline{\text{TNA:}} \quad C_6H_4N_4O_6 \;\text{----}\; 2\,H_2O_{(g)} + 4\,CO + 2\,N_2 + 2\,C_{(s)} \quad (6)$$

$$\underline{\text{DATB:}} \quad C_6H_5N_5O_6 \;\text{----}\; 2.5\,H_2O_{(g)} + 3.5\,CO + 2.5\,N_2 + 2.5\,C_{(s)} \quad (7)$$

$$\underline{\text{TATB:}} \quad C_6H_6N_6O_6 \;\text{----}\; 3\,H_2O_{(g)} + 3\,CO + 3\,N_2 + 3\,C_{(s)} \quad (8)$$
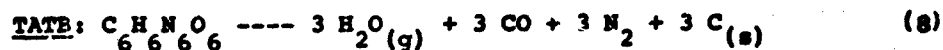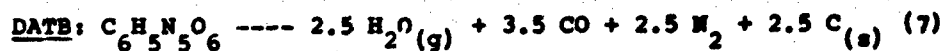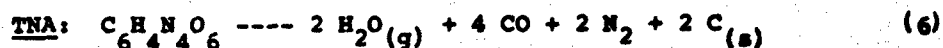
The measured heats of formation (18, 19, 20) are

$$\Delta H_{(TNB)} = -11.40 \text{ k cal/mole,}$$

$$\Delta H_{(TNA)} = -20.07 \text{ k cal/mole,}$$

$$\Delta H_{(DATB)} = -29.23 \text{ k cal/mole,}$$

$$\Delta H_{(TATB)} = -36.85 \text{ k cal/mole.}$$

Using the heat-of-formation data (37) of the decomposition products, the heats of reaction are calculated to be as follows, with the detonation energy from the aquarium measurements (Table 6) shown in parenthesis:

$$Q_{(TNB)} = 937 \text{ cal/g} \quad (811),$$

$$Q_{(TNA)} = 903 \text{ cal/g,}$$

$$Q_{(DATB)} = 875 \text{ cal/g} \quad (800),$$

$$Q_{(TATB)} = 857 \text{ cal/g} \quad (829).$$

The calculated Q values over estimate the experimental detonation energies by 3 percent for TATB, 9 percent for DATB and 13 percent for TNB. The calculated values decrease as the molecular weight of the species increases but the trend in the

experimental values indicates the detonation energy is approximately the same for each series member.

4.2 **Halford-Kistiakowsky-Wilson Equation of State.** By following the calculation scheme outlined in Appendix A, the Halford-Kistiakowsky-Wilson (HKW) equation of state (33) was used to obtain theoretical values of the detonation parameters for these compounds, Table 7.

TABLE 7

Calculated Detonation Parameters

Compound	ρ_o (g/cm^3)	D(m/sec)	P (kb)	V(cm^3/g)	T (°K)	Q(cal/g)
TNB	1.6	7082	181.4	.4837	2950	937
TNA	1.6	7055	179.8	.4839	2839	903
DATB	1.6	7010	170.3	.4865	2638	875
TATB	1.6	7055	171.2	.4906	2574	857

The constant detonation velocity of 7050 (constant to 0.6%) meters per second obtained for the four compounds is in agreement with the experimental data first, in that the velocities for all, at a given initial density, are equal; and second, at the initial density of 1.60 g/cm^3 the experimentally observed velocity was 7040 m/sec. This unusually-close agreement between the calculated and observed detonation velocity values testify to the applicability of the HKW equation of state to the detonation reactions of organic explosives of the type discussed in this report.

The calculated detonation pressures appear to be about 15 per cent low, compared to the values experimentally obtained with shocked water as the pressure-measuring device. Further refinement of the data, both theoretical and experimental, will have to be performed before this difference can be reconciled.

The detonation temperatures, ranging from 2574 for TATB to 2950 for TNB, are consistent with the decrease in the detonation energy calculated as the molecular weight of the species increases.

5. SENSITIVITY TO SLOWLY APPLIED SHOCKS

    5.1 Impact Sensitivity and Oxygen Balance. The sensitivity
of the explosives in this chemically related series, to relatively
slowly applied, low pressure, mechanical shocks (as are developed
in the impact hammer test), shows a monotonic decrease, with an
increase in the number of amino groups. TNB and picramide have
impact sensitivities (50% points) of 103 and 177 cm respectively
on the NOL impact hammer machine (38); TATB and DATB do not
initiate, even at the maximum height (320 cm) of the NOL machine.
This ordering of sensitivity of the compounds is the same as the
ordering of their heats of formation: the most sensitive, TNB,
has the lowest heat of formation. As demonstrated by Kamlet (4)
a correlation exists between impact sensitivity and oxygen balance
for structurally related groups of explosives containing $C-NO_2$,
or $N-NO_2$ bonds. This correlation for TNB, TNA, DATB and TATB is
shown in Table 8 where the oxygen balance (to CO) per 100 grams
of the compound (i.e., OB/100) has been computed by the equation,

$$OB/100 = \frac{100\ (2n_O - n_H - 2n_C)}{\text{Mole Wt. H.E.}} \qquad (9)$$

and the n's represent the number of atoms of the particular
element, in one molecule of explosive.

TABLE 8

Correlation of Impact Sensitivity with Oxygen
Balance and Heat of Formation

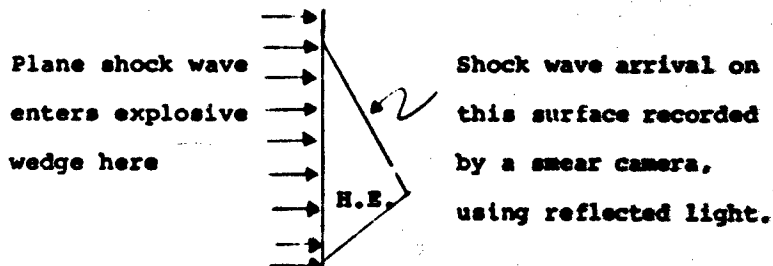| Compound	Molecular Formula	Mole Wt.	HFE (K cal/mole)	$\frac{OB}{100g}$	Impact Sensitivity* Height (cm)
TNB	$C_6H_3N_3O_6$	213	-11.40	-1.40	103
TNA	$C_6H_4N_4O_6$	228	-20.07	-1.75	177
DATB	$C_6H_5N_5O_6$	243	-29.23	-2.06	>320
TATB	$C_6H_6N_6O_6$	258	-36.85	-2.33	>320

*Reference (38)

Thus, in Table 8, the (absolute) OB/100 value increases from
1.40 TNB) to 2.33 (TATB) as the impact hammer values increase
from 103 (TNB) to >320 (TATB).

The impact hammer data shows that all members of this series of compounds are considerably less sensitive to mechanical shocks of this type than Composition B (impact hammer 50 percent point equals 65 ± 5 cm). As will be seen shortly, when the pressure pulse is delivered more rapidly as in the transmission of a shock wave, the sensitivities of several of these compounds are very similar to that of Composition B.

6. SENSITIVITY TO RAPIDLY APPLIED SHOCKS

6.1 Wedge Test Measurements. The initiation of detonation in solid explosives by shock waves transmitted through air, water, or solids, generally occurs within a few microseconds. The NOL wedge test (12, 28) is designed to study within such short times, the details of the build-up-to-detonation, as a function of the input shock pressure. In this test an explosive wedge is impacted by a plane shock wave from an explosively-driven plate, usually brass.

Plane shock wave enters explosive wedge here

Shock wave arrival on this surface recorded by a smear camera, using reflected light.

H.E.

The velocity of the transmitted shock wave, as the wave advances through the explosive wedge, is obtained as a function of the distance travelled by the shock through the wedge. From this set of data a large amount of information can be inferred concerning the behavior of the test explosive specimen. For example, one can determine one point on the Hugoniet curve for the unreacted explosive from these measurements (12). More important, since one obtains a set of values of the velocity of the wave (in the wedge) as a function of its penetration into the wedge, one gets a detailed picture of how this shock builds up from a (presumably) inert shock into an accelerated shock, and (finally) into a steady-state detonation. Tables 9 and 10 contain the various data obtained from the wedge test.

Figure 2 shows a typical curve for the build-up to detonation in a 25° DATB wedge, along with curves for pressed and cast Comp B. The initial shock velocity in the DATB was 4750 m/sec. The amplitude of this shock was 76.5 kilobars. The outstanding feature of this curve is that the instantaneous shock velocity within the explosive rises 10 to 20% above the normal detonation velocity (7600 m/sec) before receding and stabilizing at the normal detonation

TABLE 9

Wedge Test Parameters for Pure DATB, TATB, and TNB

Shot No.	Brass Thick (cm)	Initial Shock Velocity H.E. (m/sec)	Initial Particle Velocity H.E. (m/sec)	Initial Shock Pressure H.E. (kb)	Initial Compression H.E. (V/V$_o$)	ρ_o H.E. (g/cm^3)	D (Final) (m/sec)
DATB							
1	1.27	4670	1167	99.2	0.750	1.820	7640
2	1.27	4660	1167	99.3	0.750	1.825	7460
3	2.54	4870	972	85.4	0.800	1.803	7620
4	2.54	4700	979	82.8	0.792	1.799	7700
5	3.81	4736	892	76.6	0.810	1.813	7590
6	3.81	4767	892	76.5	0.815	1.810	7500
TATB							
1	2.54	4612	976	83.7	0.788	1.862	Failed to Detonate
2	1.27	5140	1140	109.1	0.778	1.862	
3	1.27	5200	1129	109.3	0.783	1.863	
4*	1.27	5200	1129	106.0	0.783	1.800	6200
TNB	1.27	Only Reactive Shock Was Observed				1.372	6400

* 30-degree wedge, maximum thickness 3.10-cm.

TABLE 10

Wedge Test Parameters for Plastic-Bonded Compositions of DATB and TNA

| Shot No.	Brass Thick (cm)	Initial Shock Velocity H.E. (m/sec)	Initial Particle Velocity H.E. (m/sec)	Initial Shock Pressure H.E. (kb)	Initial Compression H.E. $(v/v)_o$	ρ_o H.E. (g/cm^3)	D (m/sec)
DATB/BRL 2741 (95/5)							
1*	1.27	4820	1164	99.4	0.759	1.77	7350
2	2.54	4720	982	82.0	0.792	1.77	Failed to Detonate
DATB/EPON (95/5)							
1	2.54	5120	971	96.0	0.810	1.73	7350
TNA/Zytel (95/5)							
1	2.54	4780	993	77.7	0.792	1.637	7200
2	3.81	4698	909	70.5	0.822	1.650	7400

* 32-degree wedge, maximum thickness 3.10-cm.
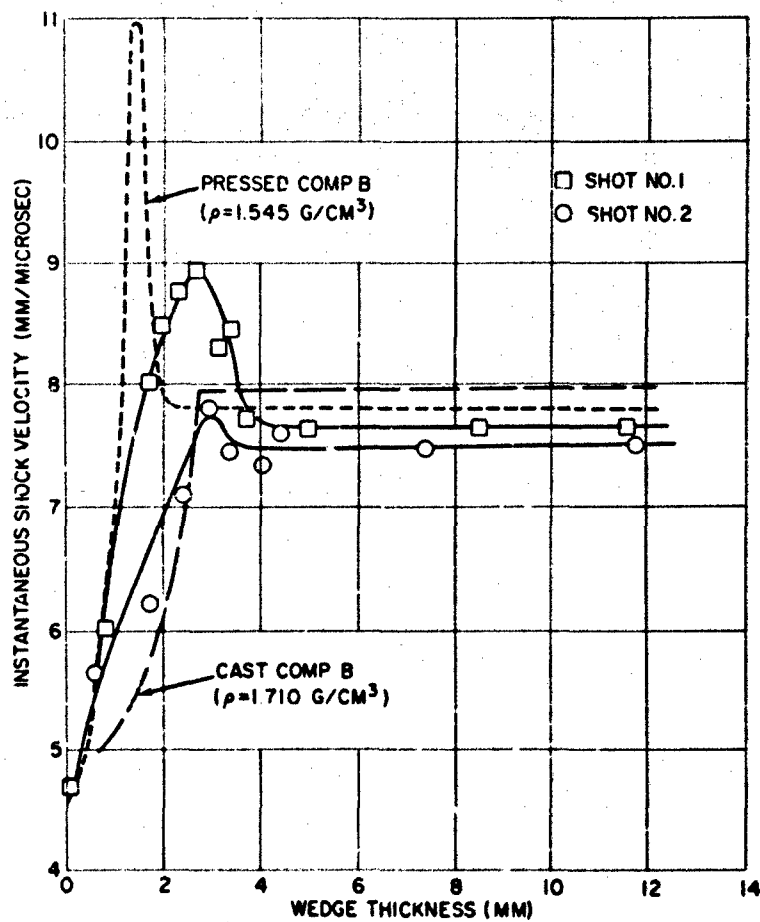
FIG. 2 INSTANTANEOUS SHOCK VELOCITIES IN DATB AS A FUNCTION OF SHOCK
PENETRATION DEPTH COMPARED TO COMP B.

velocity. A surprising result shown in this curve is that (other
than the velocity "overshoot") the build-up in DATB is not too
different from that of cast Composition B (12). This marked
difference from its behavior in the impact hammer test shows
that the sensitivity of DATB to mechanical shocks is strongly
dependent on the rate of shock loading.

TATB at an initial density of 1.86 g/cm^3 when formed into a
25° wedge (maximum thickness 1.3 cm) did not produce an accelerating
shock wave which built up to detonation, even though a pressure of
109 kb was transmitted to the wedge. However, when a 32° wedge
(maximum thickness 3.1 cm) was used to provide a longer shock run,
and the initial shock pressure transmitted to the wedge was 106 kb,
a pronounced velocity overshoot reaching 11,000 m/sec occurred
after the shock had penetrated 1.0 cm into the wedge. In contrast
to the velocity overshoots noted in the DATB results with 25°
wedges, this shock wave did not settle to 7900 m/sec, the normal
detonation velocity of TATB at 1.86 g/cm^3. Instead the wave
velocity receded to a steady value of only 6200 m/sec for the
remaining wedge thickness.

Wedges of suitable quality were not easily machined from
high density pellets of picramide and trinitrobenzene because
the pellets tended to fall apart during machining. By replacing
the wedge (in the wedge test) with cylindrical pellets of various
thicknesses, build-up-to-detonation data, analogous to that of
the wedge test were obtained. When picramide pellets, 1 to 5-mm
thick were subjected to a transmitted shock of 90 kb an initial
(inert) shock wave developed having a velocity of 5000 m/sec.
High velocity detonation was obtained in pellets 3 to 4 mm thick
as evidenced by the appearance of luminous product gases in the
camera record. In wedge tests of picramide, plastic-bonded with
zytel (95/5), velocity overshoots exceeding 8500 m/sec were
observed (Figure 3). The data points for these curves were
obtained by subjecting 30-degree wedges to transmitted pressures
of 77.7 and 70.5 kb.

In 3 to 10-mm thick trinitrobenzene pellets of density
1.69 g/cm^3, shocked to about 90 kb, an initial instantaneous
shock wave velocity of 6800 m/sec was obtained. Since this
velocity was just 200 m/sec less than the normal detonation
velocity obtained for 5.1-cm diameter TNB, we conclude that the
3-mm pellets of TNB were initiated to full detonation within a
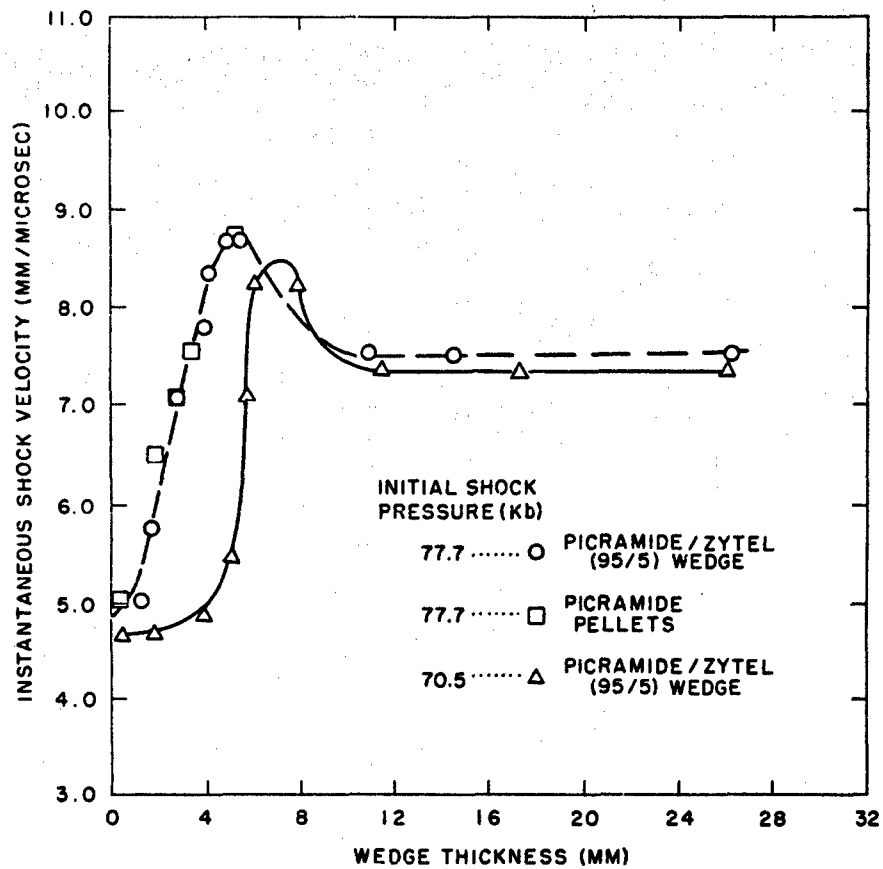thickness less than 1-mm by the 90 kb shock.

FIG. 3 INSTANTANEOUS SHOCK VELOCITIES AS A FUNCTION OF
SHOCK PENETRATION DEPTH FOR PICRAMIDE/ZYTEL (95/5)

The wedge test data for the above compounds are listed in Table 9. Table 10 contains the data for some of these compounds, plastic-bonded with various binders:

DATB/BRL 2741* (95/5), DATB/EPON** (95/5), and TNA/Zytel*** (95/5).

When a 25-degree wedge of DATB/BRL 2741, was shocked, the shock wave failed to build up to detonation even though the initial pressure developed within the wedge was 82 kb. On the other hand build-up-to-detonation (from an initial velocity of 5120 m/sec) with a 86 kb shock wave pressure was obtained with a standard 1.3-cm high, 25-degree wedge of DATB/EPON 1001 (95/5). (This difference could be related to the difference in behavior between the two plastics.) When the shock run for the DATB/BRL 2741 was increased to 3.1 cm (using a 30-degree wedge), and the transmitted pressure increased to 100 kb, a smooth build-up-to-detonation was obtained.

7. CONCLUSIONS

7.1 **Detonation Properties.** The steady state detonation parameters of TNA, TNB, DATB and TATB are insensitive to the number of amino groups.

The detonation velocity-charge density relationship $D = 7480 + 2852 \rho$ (g/cm^3), and measured detonation energy of 81.5 ± 15 cal/g are the same for each series member.

Detonation velocities of TNA, TNB, DATB, and TATB at loading densities of 1.6 g/cm^3 are predicted within 2% by the hydrodynamic theory, using the HKW equation of state.

At charge densities of 1.80 g/cm^2, the measured detonation pressures of DATB and TATB are 251.0 kb and 259.4 kb respectively. A detonation pressure of 174.6 kb was measured for TATB at 1.50 g/cm^2. At 1.64 g/cm^2 a detonation pressure of 219.2 kb was measured for TNB.

7.2 **Sensitivity.** The shock sensitivity and failure diameter, are functions of the number of amino groups, heats of formation and oxygen balance. From the most sensitive to shocks, to the least sensitive, both the heat of formation and oxygen balance increase as one goes from TNB to TNA, DATB, and TATB; i.e. as the number of NH_2 groups increases. TNA gave detonation failures at diameter about 0.3-cm; DATB and TATB fail at 0.53-cm and 1.3-cm diameters respectively.

---

*BRL 2741 (Phenolic Resin), The Bakelite Corporation, New York City, New York.
**EPON (Epoxy Resin); Shell Epon 1001; Shell Chemical Company, Emeryville, California.
***Nylon, trade name.

The sensitivity of these compounds to mechanical shocks, as exhibited in the NOL wedge test, decreases as the number of NH_2-groups increases. Thus even though a 100 kb pressure developed within the wedge, TATB failed to detonate. However under the same shock pressure normal detonation was developed in 1.8 mm by DATB and even less than 1.8 mm by both TNA and TNB.

UNCLASSIFIED

CONFIDENTIAL
NOLTR 63-81

REFERENCES

(1)   R. L. Datta and N. R. Chatterjee, J. Chem. Soc. 115, 1006
      (1919).
(2)   R. Robertson, J. Chem. Soc. 119, 1 (1921).
(3)   Arthur D. Little, Inc. Report, "Study of Pure Explosive
      Compounds. Part II, Correlation of Organic Structure with
      Explosive Properties from Existing Data", (2 Jan 1947).
(4)   M. J. Kamlet, 3rd ONR Symposium on Detonation; Princeton,
      N. J., (Sept 26-28, 1960).
(5)   I. F. Blinov, Chem. Abstracts 419 (1959).
(6)   F. P. Bowden and A. D. Yoffee, "Fast Reactions in Solids",
      Butterworth's Scientific Publications, London (1958).
(7)   J. Wenograd, NAVORD Report 5730 (1957) (Confidential).
(8)   J. L. Copp, S. F. Napier, T. Nash, W. J. Powell, H. Shelley,
      H. K. Ubbelohde and P. Woodhead, Phil. Trans. Roy. Soc.
      (London) A 241,197 (1949).
(9)   G. Hersberg and R. Walker, Nature (London) 161, 647 (1948).
(10) C. H. Winning, Nature (London) 177, 33 (1956).
(11) M. A. Cook, L. L. Udy, ARS Journal 21, 52 (1961).
(12) J. M. Majowicz and S. J. Jacobs, NAVORD Report 5710 (1958).
(13) M. A. Cook, The Science of High Explosives, Reinhold Pub-
      lishing Corporation, New York (1958).
(14) D. Price and I. Jaffe, ARS Journal 31, 595 (1961).
(15) Fluscheim, Z. ges Schiess u Sprengstoff 185 (1913).
(16) Stellbacher, Z. ges Schiess u Sprengstoff 144 (1916).
(17) Van Duin, Von Lennep, Rec. Trav. Chem. 39, 145 (1920).
(18) Burlot, Mem. Poudres 29, 226 (1939).
(19) Nedard and Thomas, Mem. Poudres 31, 173 (1949).
(20) D. V. Sickman, NOL Memorandum, 1 Oct 1959.
(21) J. T. Loftus and D. Gross, Natl. Bur. Standards Report 6548
      (23 Sept 1959).
(22) J. M. Rosen, NOL private communication.
(23) L. N. Stesik and L. N. Akimova, J. Phys. Chem. (USSR; Eng.
      translation) 33, 148 (1959).
(24) H. Kast, Spreng-u-Zundstoffe 70, 100 (1921).
(25) Koehler and Desvergnes, Mem Poudres 19, 217 (1922).
(26) K. G. Shipp and M. E. Hill, NAVORD Report 6013, (Mar 1958)
      (Confidential).
(27) J. R. Holden, A. H. Rosen, J. M. Rosen, NAVORD Report 6299,
      (Mar 1959) (Confidential).
(28) N. L. Coleburn, B. E. Drimmer, T. P. Liddiard, Jr., NAVORD
      Report 6750 (Oct 1960).
(29) W. C. Holton, NAVORD Report 3968 (Dec 1954) (Confidential).
(30) M. A. Rice and J. M. Walsh, J. Chem. Phys. 26, 824 (1957).
(31) S. J. Jacobs, NAVORD Report 4366, (Sept 1956) (Confidential).
(32) D. Price, Chem. Rev. 59, 801 (1959).
(33) G. B. Kistiakowsky and E. B. Wilson, OSRD Report 114 (1941).
(34) S. R. Brinkley and E. B. Wilson, OSRD Report 95 (1942).
(35) E. A. Christian and H. G. Snay, NAVORD Report 1508 (1956).

CONFIDENTIAL

UNCLASSIFIED

UNCLASSIFIED

NOLTR 63-81

(36) R. D. Cowen and W. Fickett, J. Chem. Phys. $\underline{24}$, 932 (1956).
(37) F. D. Rossini, D. D. Wagman, W. H. Evans, S. Levine and
      I. Jaffe, Natl. Bur. Standards (U. S.) circ. No. 500 (1952).
(38) H. Heller, NOL private communication.
(39) H. G. Snay and I. Stegun, NAVORD Report 1732, (Jan 1951)
      (Confidential).

UNCLASSIFIED

APPENDIX A

THERMO-HYDRODYNAMIC THEORY OF DETONATION

The properties of detonation waves in solid explosives have been studied by various investigators (33, 34, 35, 36) using the Halford-Kistiakowsky-Wilson equation of state,

$$P (V_m - \eta V_s) = \frac{n_g R T}{M} (1 + Xe^{BX}) , \qquad (A1)$$

$$X = \frac{K}{M} (V_m - \eta V_s) T^\alpha , \qquad (A2)$$

$$\alpha = 1/4 ,$$

$$B = 3/10 .$$

V_m and V_s are the specific volumes of the gas-solid mixture and of the solid respectively. η is the weight fraction of the solid, and n_g is the number of moles of product gases per M grams of the mixture. K is the empirical covolume parameter of the i-th gas and is a summation made over all gas species present.

In a detonation, the chemical energy released is equal to difference between the internal energy of the products and of the initial materials. The expression for M grams of explosive, assuming the incompressibility of solid products is

$$E_{(V, T)} - E_{(V_c, T_o)} = n_g \overline{c_V} (T - T_o) + \int_o^{\frac{M}{\rho}} \left(\frac{\partial E}{\partial V}\right)_T dV + Q , \qquad (A3)$$

and in terms of the Halford-Kistiakowsky-Wilson equation of state,

$$\int_o^{\frac{M}{\rho}} \left(\frac{\partial E}{\partial V}\right)_T dV = n_g RT \, \alpha \, XE^{BX} . \qquad (A4)$$

The mean ideal heat capacity, $\overline{c_V}$, in cal/mole/°K at constant volume for each decomposition product is given by

$$\overline{c_V} = \frac{1}{T - T_o} \int_{T_o}^{T} c_V \, dT . \qquad (A5)$$

A-1

$$\overline{c_V} = A + BT , \tag{A6}$$

where $A = \Sigma\, n_i\, A_1$; $B = n_i\, B_i$ are constants. The heat of reaction per mole is

$$Q = HFE - \Sigma\, n_i\, HF_i - n_g\, RT_o. \tag{A7}$$

HFE is the heat of formation of the explosive $\Sigma\, n_i\, HF_i$ is the sum of the individual molar heats of formation of the decomposition products and n_g is the number of moles of product gases. The last term in Equation (A7) is the difference between the reaction carried out at constant pressure and constant volume, assuming ideal behavior of the product gases.

The Rankine-Hugoniot equation for a reacting shock wave is

$$E_{(V,\, T)} - E_{(V_o,\, T)} = 1/2\, (P + P_o)\, (V_o - V). \tag{A8}$$

If $P \gg P_o$ and $T_o = 300°K$ (where the zero subscript refers to conditions ahead of the reactive shock (detonation), and the expressions for C_V and the HKW equation of state are used, the Rankine-Hugoniot becomes a quadratic in T,

$$BT^2 + T\,(A - B\,300°K - n_g\, \psi) - Q - A \cdot 300°K = 0, \tag{A9}$$

where

$$\psi = \frac{RF_{(x)}}{2}\left(\frac{V_o - 1}{V_m - \eta V_s} \right) - I_{(x)}, \tag{A10}$$

$$I_{(x)} = n_g\, R\, \alpha\, Xe^{BX}, \tag{A11}$$

and

$$F_{(x)} = 1 + Xe^{BX}. \tag{A12}$$

(Various I-functions have been tabulated and an iterative procedure developed by Snay (35, 39) for their use in detonation calculations.)

The internal energy of the products in the detonation wave is a function of either T and V or of P and V. If P and V are to be determined individually a second relation is required. This is furnished by the equation

$$\left(\frac{\partial P}{\partial V} \right)_{Hug.} = - \frac{P_{CJ}}{V_o - V_{CJ}} \,, \tag{A13}$$

which is derived from the Chapman-Jouquet condition,

$$D = u + C \tag{A14}$$

D is the detonation velocity, u, the particle velocity, and C, the velocity of sound at the front. $\left(\frac{\partial P}{\partial V} \right)_{Hug.}$ is the gradient of the line in the P-V diagram which represents the Rankine-Hugoniot equation. If the identity and total number of moles of product gases are fixed by an assumed decomposition equation for the explosive at a given loading density, Equation (A9) may be solved for T for each value of X. The pressure and volume for each value of X and T are calculated from the equation of state. When a number of P-V points have been obtained in this way, the Hugoniot curve can be drawn. The tangent drawn to the curve from the point on the line P = 0 at which V = V_o, determines the detonation valocity of the explosive, and the pressure and specific volume in the Chapman-Jouquet plane.

DISTRIBUTION

	Copies
Chief, Bureau of Naval Weapons	
Department of the Navy	
Washington 25, D. C.	
DIS-32	2
RRRE-5	3
RUME-11	1
RUME-32	1
RMMO-5	1
RRRE-6	2

Director, Special Projects Office
Department of the Navy
Washington 25, D. C.
 SP   1

Chief, Bureau of Ships
Department of the Navy
Washington 25, D. C.   1

Chief of Naval Research
Department of the Navy
Washington 25, D. C.
 Chemistry Branch   2

Commander, Operational Development Force
U. S. Atlantic Fleet
U. S. Naval Base
Norfolk 11, Virginia   2

Commander, U. S. Naval Ordnance Test Station
China Lake, California
 Code 556   1
 Code 4572   1
 Technical Library   2
 H. D. Mallory   1

Director, David Taylor Model Basin
Carderock, Maryland
 Dr. A. H. Keil   2

Commander, U. S. Naval Weapons Laboratory
Dahlgren, Virginia
 Technical Library   2
 Weapons Laboratory   1
 Terminal Ballistics Laboratory   1

Commanding Officer & Director
David Taylor Model Basin
Underwater Explosions Research Department, Code 780
Portsmouth, Virginia   1

Copies

Commanding Officer, Office of Ordnance Research
Box CM, Duke Station
Durham, North Carolina   1

Chief of Staff
U. S. Air Force
Washington 25, D. C.
  AFORD-AR   1

Commander, Wright Air Development Center
Wright-Patterson Air Force Base
Dayton, Ohio
  WWAD   2

APGC (PGTRI, Tech Lib)
Eglin AFB, Florida   1

Commander, Air Research & Development Command
Andrews Air Force Base
Washington 25, D. C.   1

Commanding Officer, Air Force Missile Center (MTASI)
Patrick Air Force Base, Florida   1

Commander, Air Force Cambridge Research Center
L. G. Hanscom Field
Bedford, Massachusetts   1

Defense Documentation Center
Arlington Hall Station
Arlington 12, Virginia   10

Chief, Defense Atomic Support Agency
Washington 25, D. C.   5

Atomic Energy Commission
Washington 25, D. C.
  DMA   1

Director, U. S. Bureau of Mines
Division of Explosive Technology
4800 Forbes Street
Pittsburgh 13, Pennsylvania
  Dr. R. W. Van Dolah   1

Scientific and Technical Information Facility
P. O. Box 5700
Bethesda, Maryland
  Attn: NASA Representative   1

Copies

Commanding Officer, U. S. Naval Weapons Station
Yorktown, Virginia
  R & D Division   2

Commanding Officer, U. S. Naval Ordnance Laboratory
Corona, California   2

Commanding Officer, U. S. Naval Propellant Plant
Indian Head, Maryland
  Technical Library   1
  ODTC   1

Commander, Naval Radiological Defense Laboratory
San Francisco, California
  Ruth Schnider   1

Commanding Officer, U. S. Naval Ordnance Plant
Macon, Georgia   1

Commanding Officer, Naval Ammunition Depot
Crane, Indiana   1

Commanding Officer, U. S. Naval Ammunition Depot
Navy Number Six Six (66)
c/o Fleet Post Office
San Francisco, California
  Quality Evaluation Laboratory   1

Commanding Officer,
U. S. Naval Weapons Evaluation Facility
Kirtland Air Force Base
Albuquerque, New Mexico   1

Office of Chief of Ordnance
Department of the Army
Washington 25, D. C.
  ORDGU   1
  ORDTB   1
  ORDTN   1

Commander, Army Rocket and Guided Missile Agency
Redstone Arsenal, Alabama
  ORDXR-RH   1

Copies

National Aeronautics & Space Administration
Goddard Space Flight Center
Greenbelt, Maryland   1

Director, USAF Project RAND
(Via USAF Liaison Office)
The Rand Corporation
1700 Main Street
Santa Monica, California
  Librarian   1

Lawrence Radiation Laboratory
University of California
P. O. Box 808
Livermore, California
  Technical Information Division   1
  Dr. J. Kury   1

Director, Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico
  Library   1

Director, Applied Physics Laboratory
John Hopkins University
8621 Georgia Avenue
Silver Spring, Maryland   2
  Solid Propellants Agency   1

Commander
Air Force Special Weapons Center
Kirtland Air Force Base
Albuquerque, New Mexico   1

Hercules Powder Company
Research Center
Wilmington 99, Delaware
  Technical Information Div.
  Dr. H. Skolnik   SPIA-C18   1

Aerojet-General Corporation
11711 South Woodruff Avenue
Downey, California   NORD 16881
  Dr. Louis Zernow   1

Copies

Commanding General, Picatinny Arsenal
Dover, New Jersey
  ORDBB-TH8, Technical Information   1
  ORDBB-TJ1, H. E. Section   1
  ORDBB-TK3, Prop. and Expl. Unit   1
  ORDBB-TM1, Chem. Res. Section   1
  ORDBB-TP1, Proj. Fuze Section   1
  ORDBB-TP2, GM, Rkt, and Bomb Fuze   1
  ORDBB-TP3, Init. and Spec. Dev.   1
  ORDBB-TR2, Phys. Res. Section   1
  ORDBB-TS1, Pyrotech. Lab.   1

Commanding Officer, Harry Diamond Laboratory
Connecticut Avenue & Van Ness Street, N. W.
Washington 25, D. C.
  Ordnance Development Laboratory   1
  M. Lipnick (Code 005)   1

Commanding Officer, Engineer Research & Development
Laboratory, U. S. Army, Ft. Belvoir, Virginia
  Technical Intelligence Branch   1

Commanding General, U. S. Army Proving Ground
Aberdeen, Maryland
  Technical Library   1
  Dr. R. J. Eichelberger   1
  M. Sultanoff   1

Commanding General, Redstone Arsenal
Huntsville, Alabama
  Technical Library   1

Commanding Officer, Chemical Corps
Chemical & Radiological Laboratory
Army Chemical Center, Maryland   1

Commanding Officer
Fort Dietrick, Maryland   1

Commanding General, U. S. Army Ordnance Ammunition Center
Joliet, Illinois   1

Commanding Officer, Holston Ordnance Works
Kingsport, Tennessee   1

Commanding General, White Sands Proving Ground
White Sands, New Mexico   1

Copies

Aerojet-General Corporation
P. O. Box 1947
Sacramento, California   NOW63-005
Tech Information Office   1
Dr. Kirchner   1
Dr. Whitmore   1

University of Utah
Salt Lake City, Utah   NOW61-04116
Dr. Melvin Cook, Epl. Research Group   1

E. I. duPont deNemour
Eastern Laboratories
Explosives Department
Gibbstown, New Jersey   N60921-7008
  Dr. L. Coursen   1

CATALOGING INFORMATION FOR LIBRARY USE

BIBLIOGRAPHIC INFORMATION

	DESCRIPTORS	CODES		DESCRIPTORS	CODES
SOURCE	NOL technical report	NOL TR	SECURITY CLASSIFICATION AND CODE COUNT	_____ 30	____
REPORT NUMBER	63-81	630751	CIRCULATION LIMITATION		
REPORT DATE	May 1963	0563	CIRCULATION LIMITATION OR BIBLIOGRAPHIC		
			BIBLIOGRAPHIC (SUPPL., VOL., ETC.)		

SUBJECT ANALYSIS OF REPORT

DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Explosion	EXPS	Aniline	ANIL	Explosive	EXPL
Symmetrical	SYMM	Diamino	DIAM	Charge	CHAR
Trinitro	TRIT	Groups	GOUP	Chapman	CHAP
Benzene	BENZ	Heat	HEAT	Jouquet	JOUQ
Amino	AMIN	Formation	FORM	Wedge	WEDG
Substituted	SUBT	Oxygen	OXYG	Explosives (Test)	EXPLT
Shock	SHOC	Balance	BALN		
Sensitivity	SENV	Mechanical	MECA		
Failure	FAIL	Detonation	DETO		
Diameter	IMET	Pressure	PRES		
Tetra	TERA	Velocity	VELG		
Nitro	NIRO	Measurements	MEAU		

PWC-NOL-899/2 (6-62)

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-81)
THE EXPLOSIVE PROPERTIES OF THE AMINO-SUBSTI-
TUTED, SYMMETRICAL TRINITROBENZENES (U), by
N. L. Coleburn and B. E. Drimmer. May 1963.
v.p. BuWep task RUME 4E 000/212-1/F008-10-004.
CONFIDENTIAL

The shock sensitivity and failure diameter of
1,3,5 - trinitrobenzene (TNB); 1 - amino 2,4,6-
trinitrobenzene (TNA); 1,3 - diamino 2,4,5-
trinitrobenzene (TAT3) are functions of the
number of amino groups, heats of formation and
oxygen balance. TNB is the most sensitive to
mechanical shocks. As the number of amino
groups increase the detonation failure dia-
meters increase.

1. 1,3,5-Trin-
   itrobenzene
2. 1-amino 2,4,
   6-trinitro-
   benzene
3. 1,3-Diamino
   2,4,6-trini-
   trobenzene
4. Explosives -
   Sensitivity
I. Title
II. Coleburn,
    Nathaniel L.
III. Drimmer,
     Bernard E.,
     jt. author
IV. Project

Abstract card is
Unclassified